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**Bonn**

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(54) **METHOD FOR CONSTRUCTING A DIPOLE ANTENNA**

(75) Inventor: **Kenlyn S. Bonn**, Lakewood, CO (US)

(73) Assignee: **Covidien LP**, Mansfield, MA (US)

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(52) **U.S. Cl.**
USPC ...................... **29/600**; 29/592.1; 343/700 MS

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See application file for complete search history.

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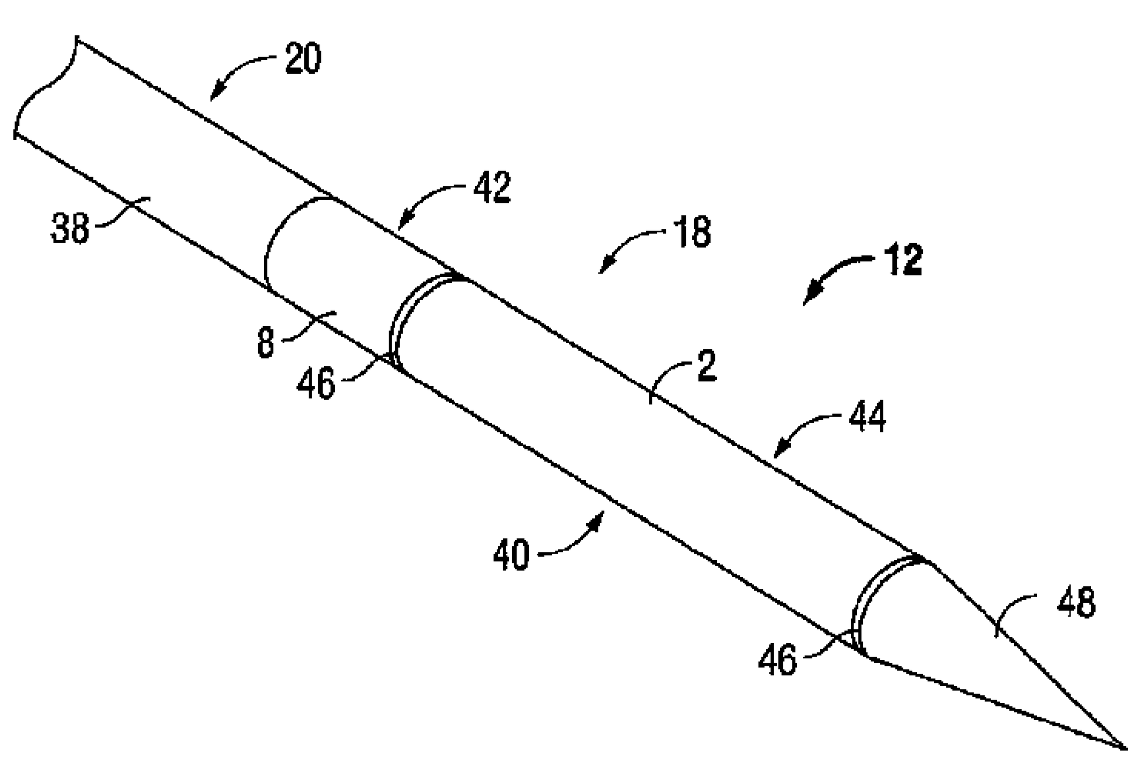
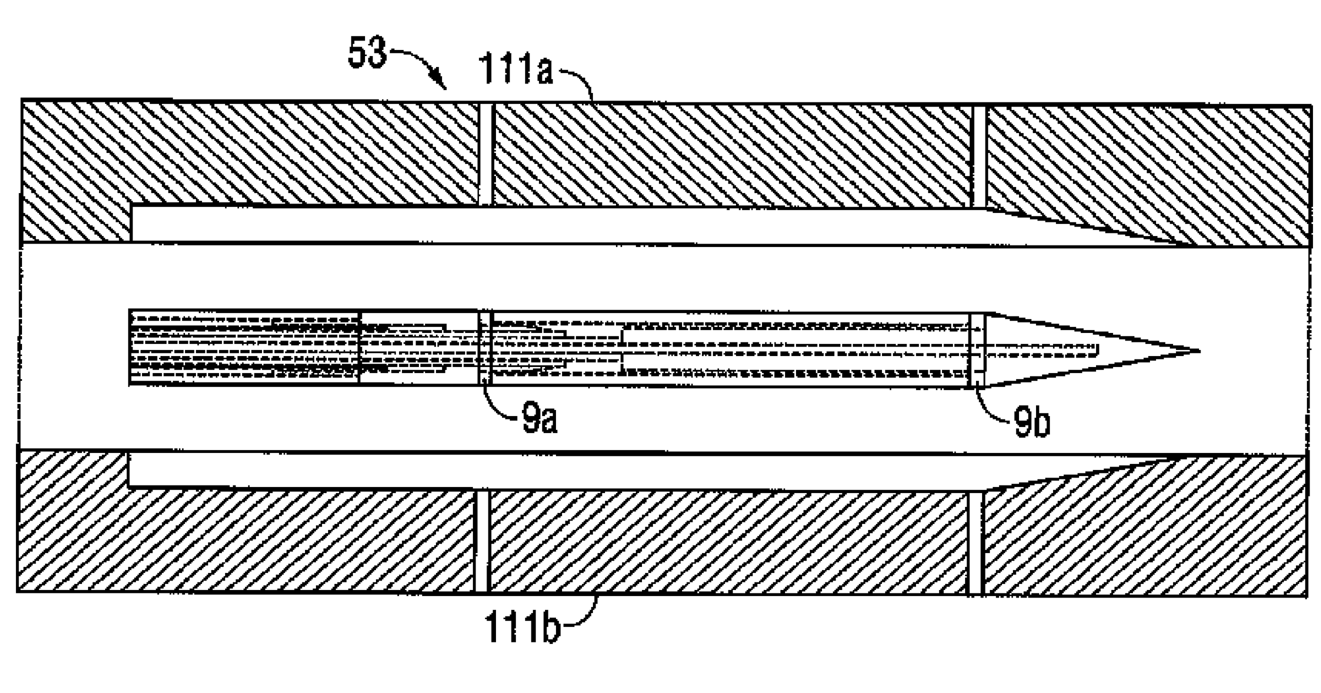
*Primary Examiner* — Minh Trinh

(57) **ABSTRACT**

A method of fabricating a microwave antenna assembly is disclosed. The fabrication method includes providing a proximal portion having an inner conductor and an outer conductor, the inner conductor extending at least partially therein. The method further includes providing a distal portion disposed distally of the proximal portion, with the inner conductor extending at least partially therein. A high strength material may be injected from an inflow slot to an outflow slot of the distal portion such that the material is disposed in-between the inner conductor and a ceramic layer. The material bonds the distal portion and the ceramic layer to the proximal portion while providing mechanical strength to the distal portion.

**3 Claims, 6 Drawing Sheets**



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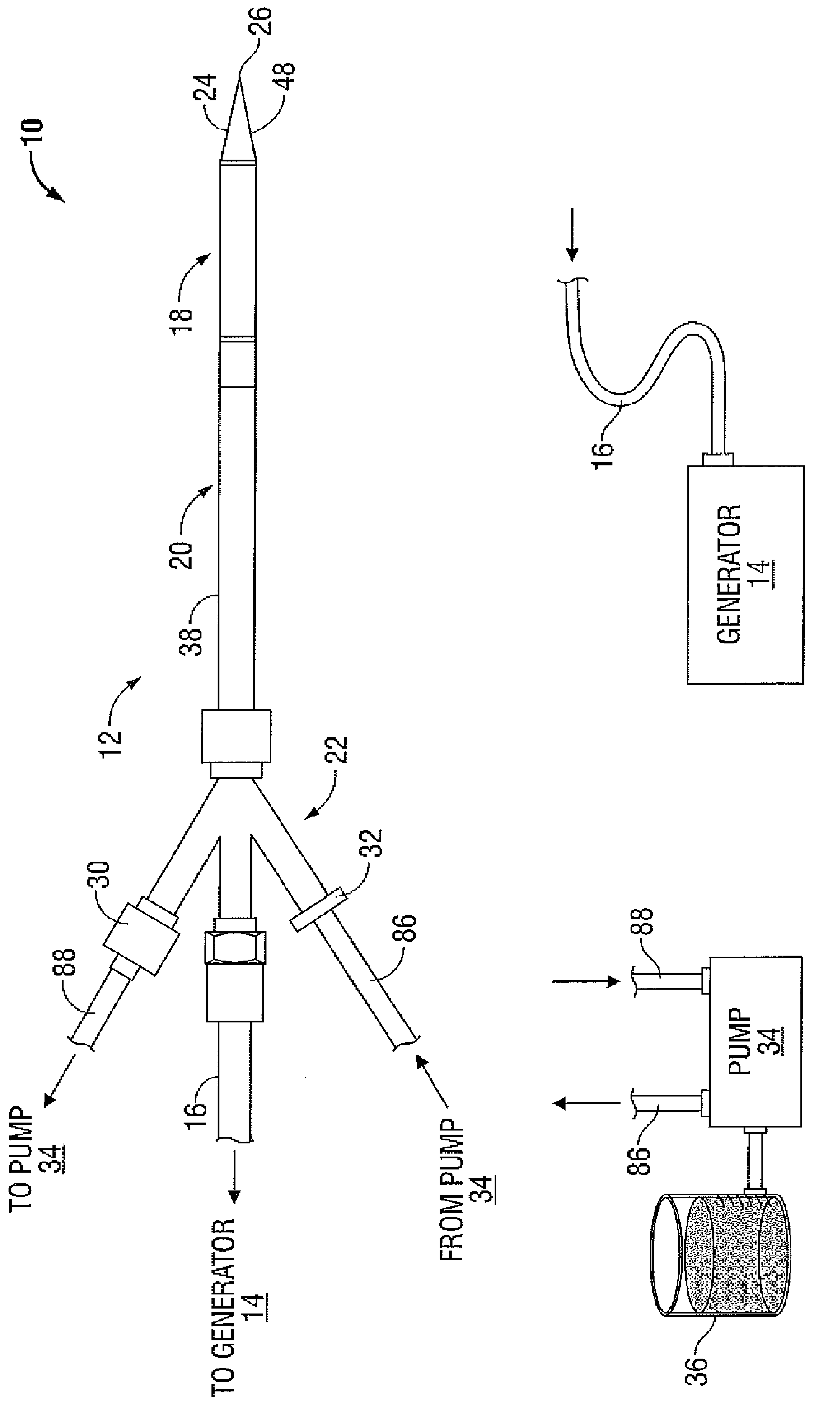
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FIG. 1

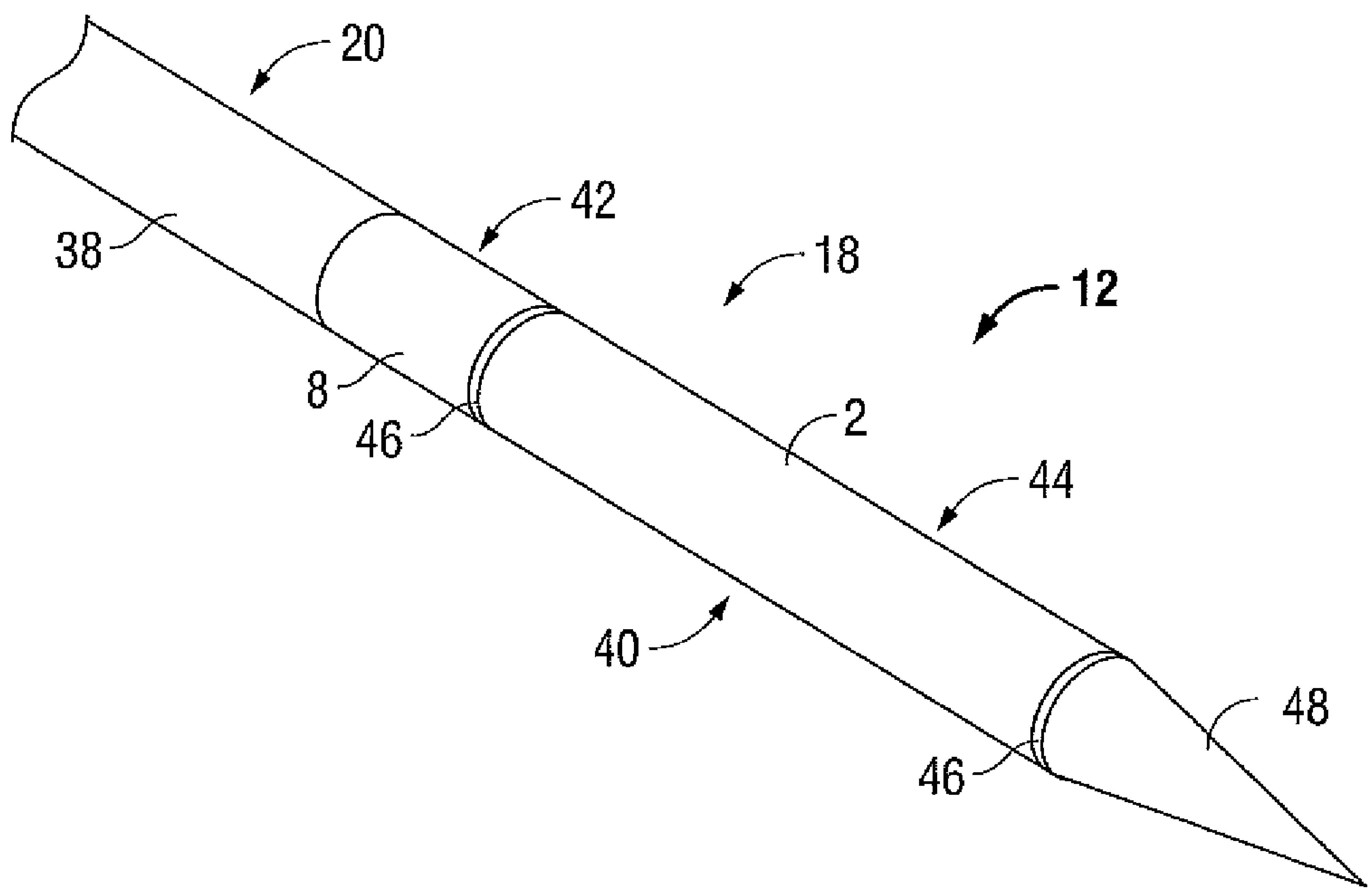


FIG. 2

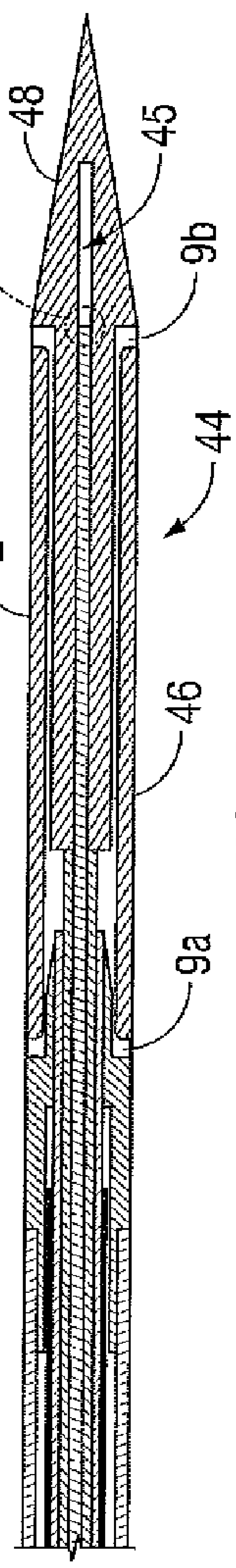

FIG. 3

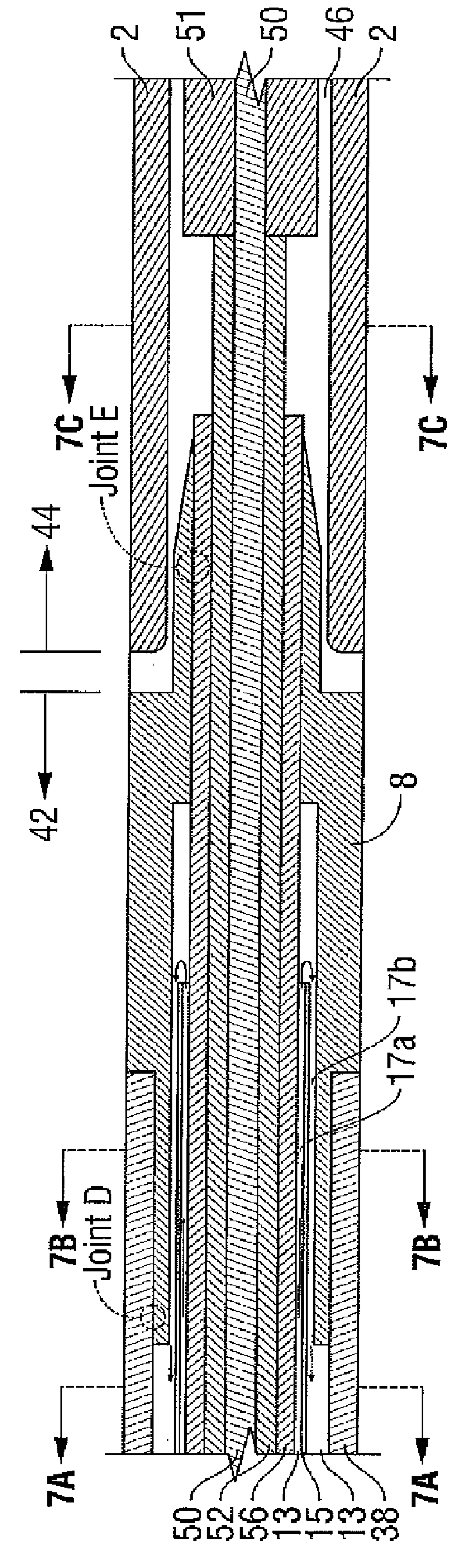

FIG. 4

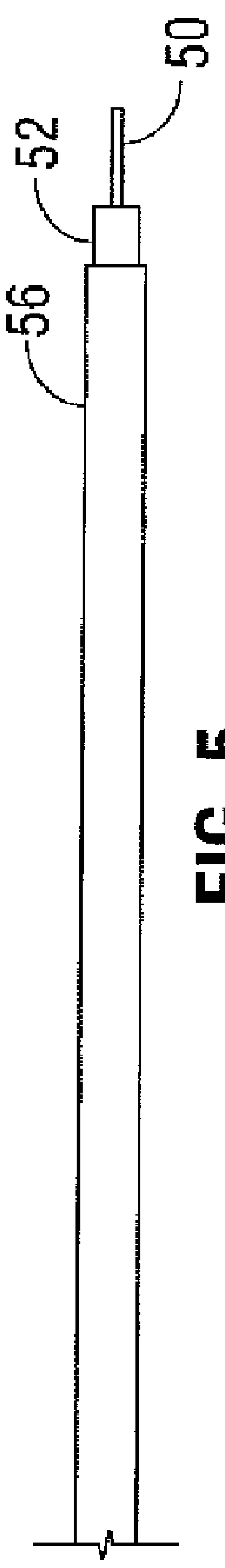

FIG. 5

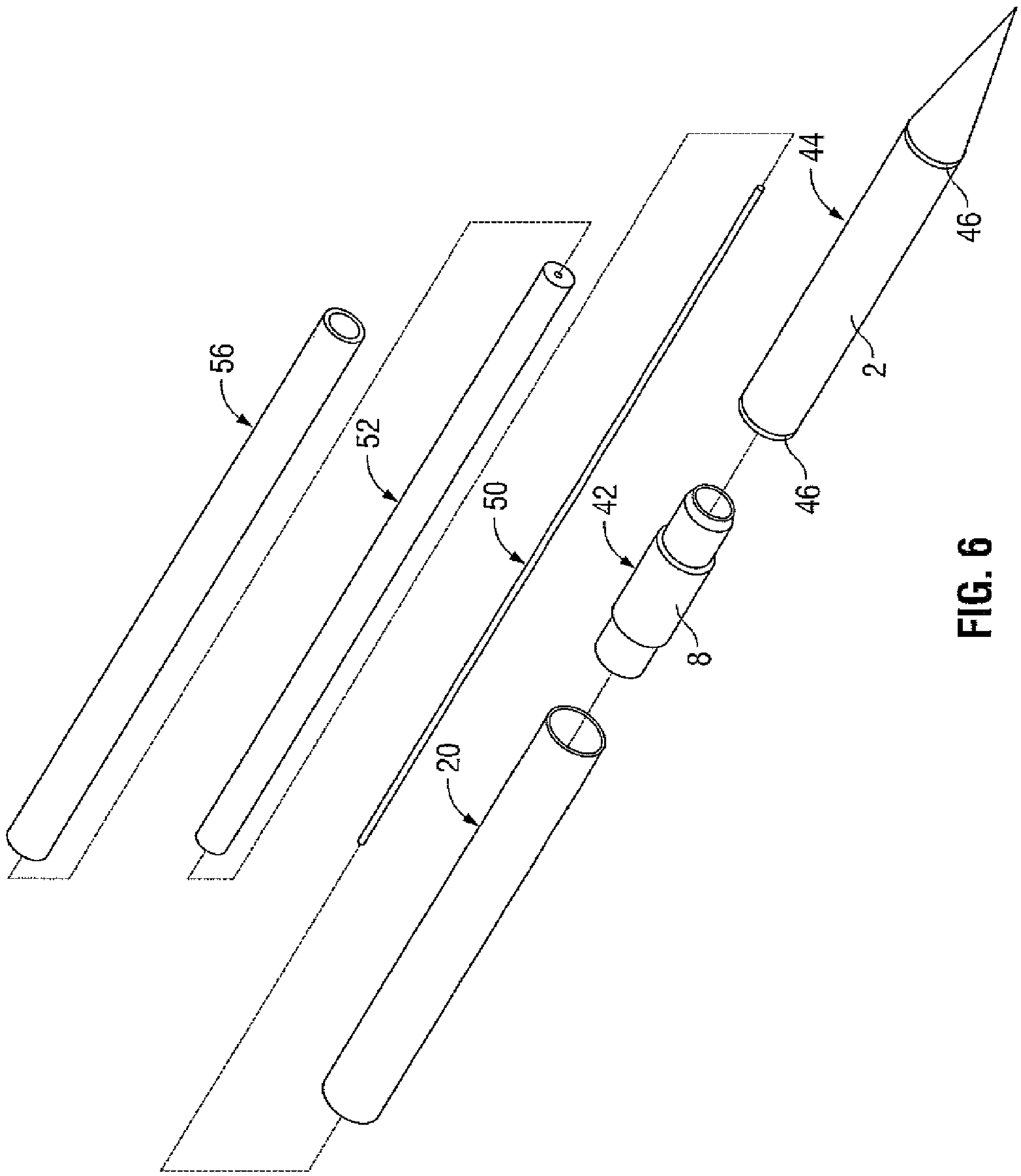


FIG. 6

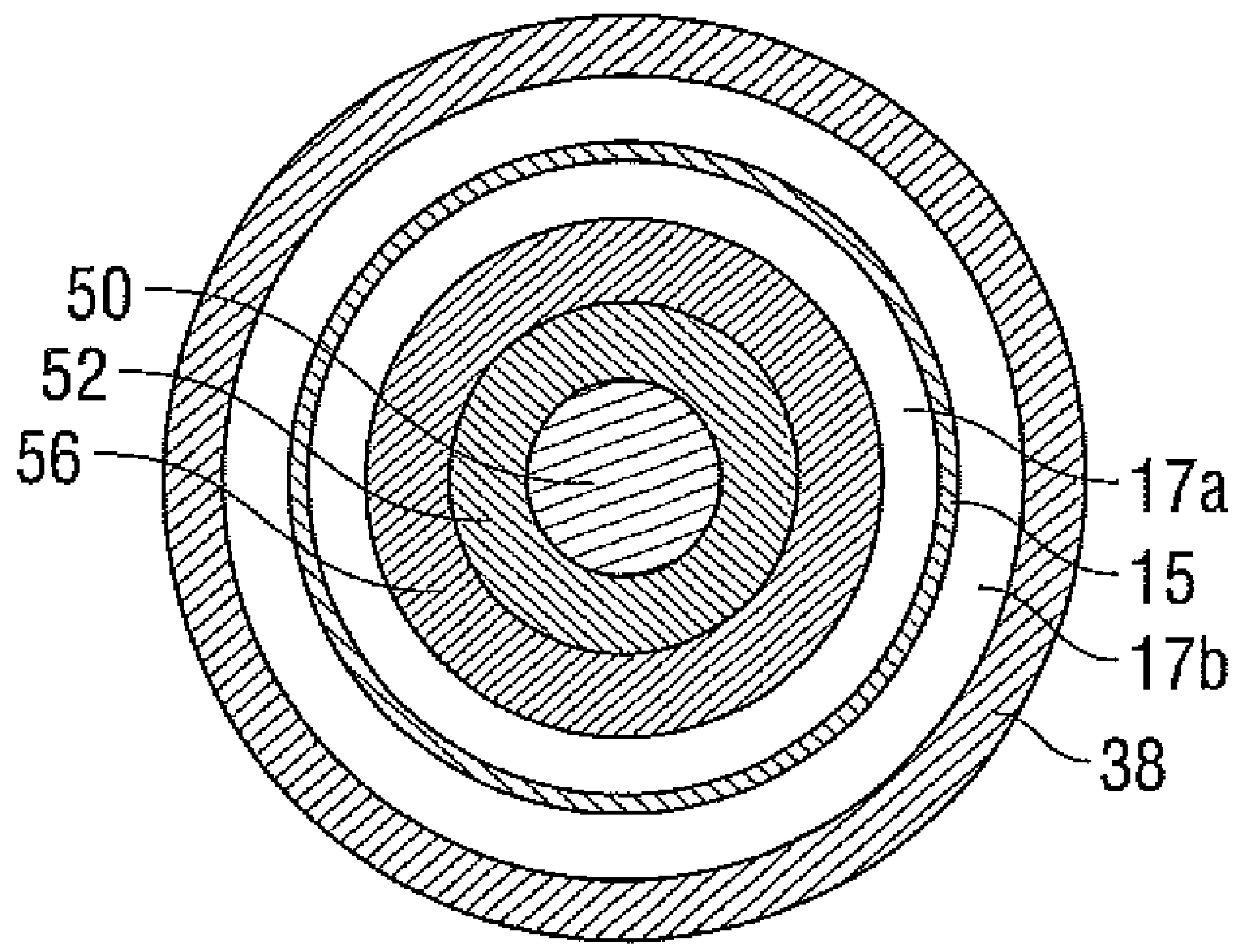


FIG. 7A

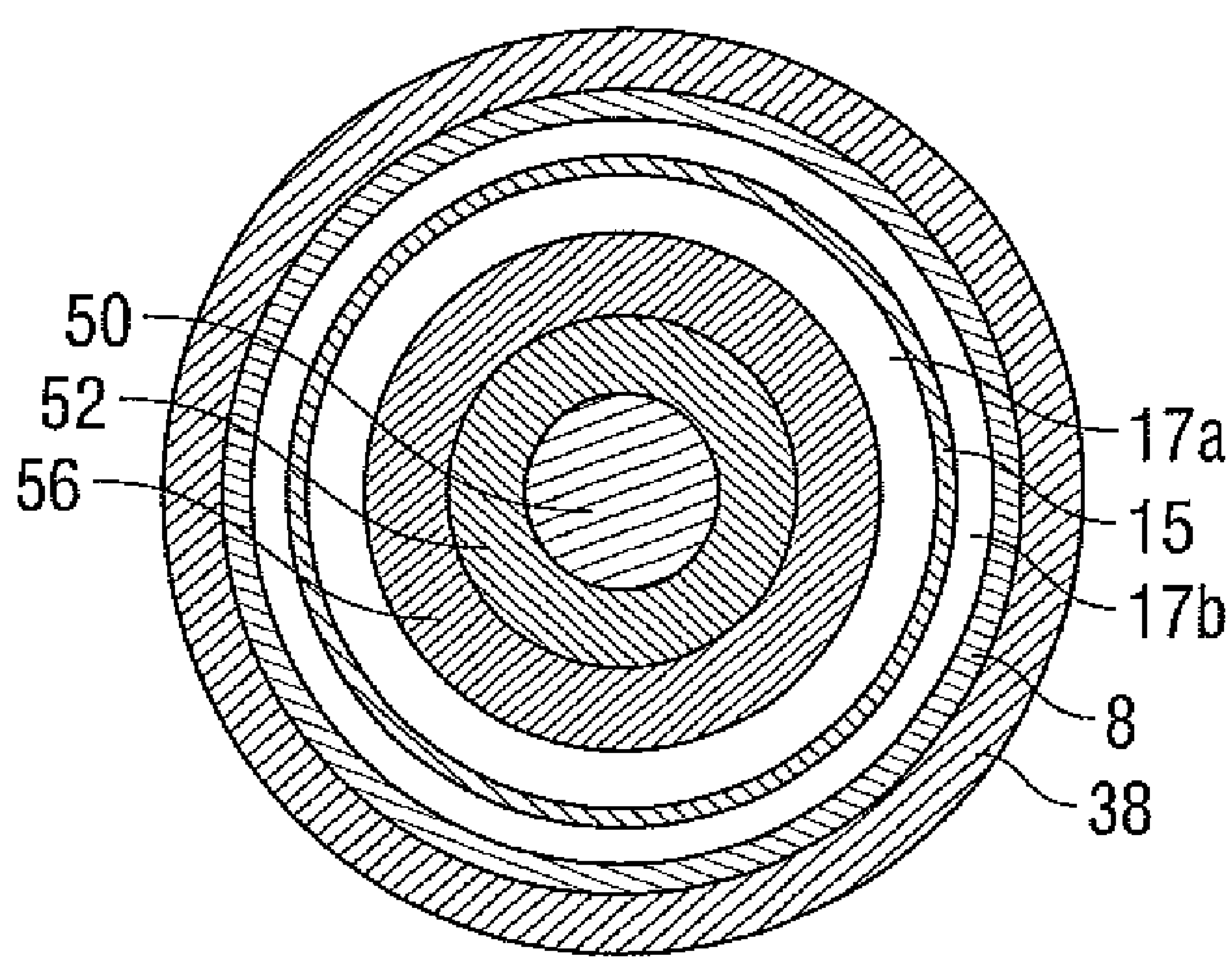


FIG. 7B

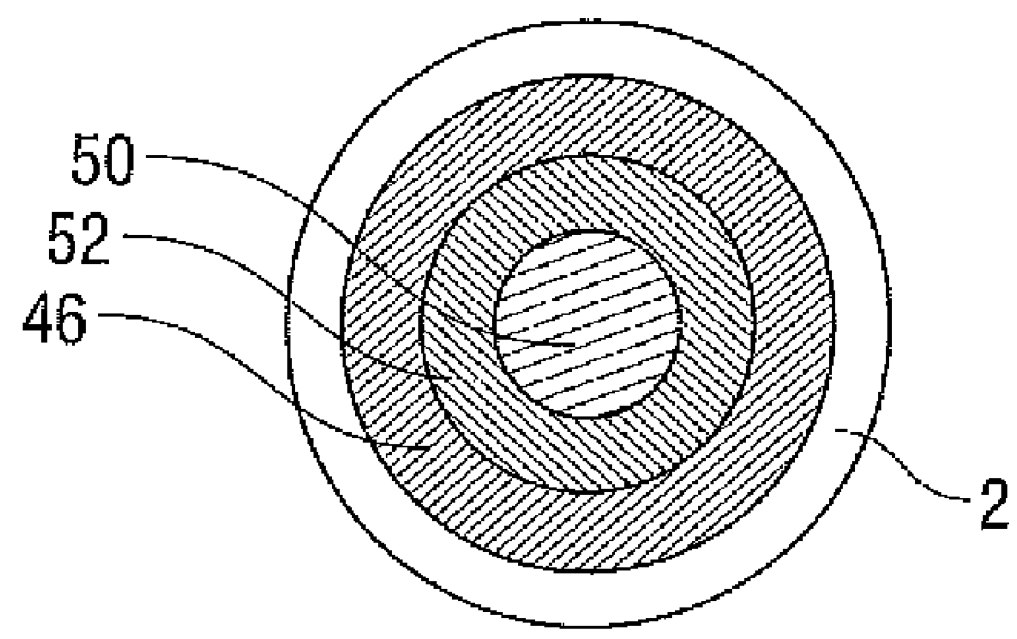


FIG. 7C

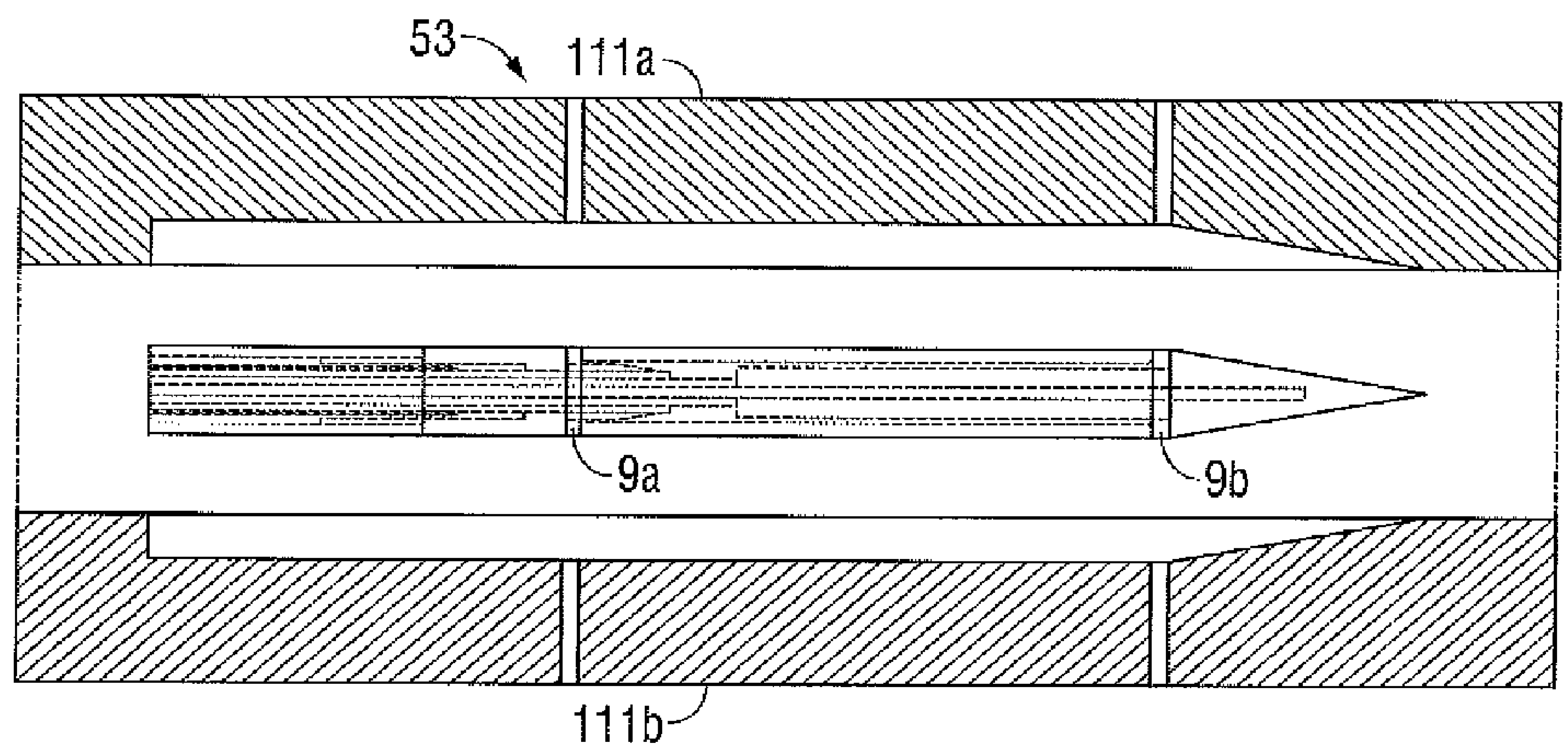


FIG. 8

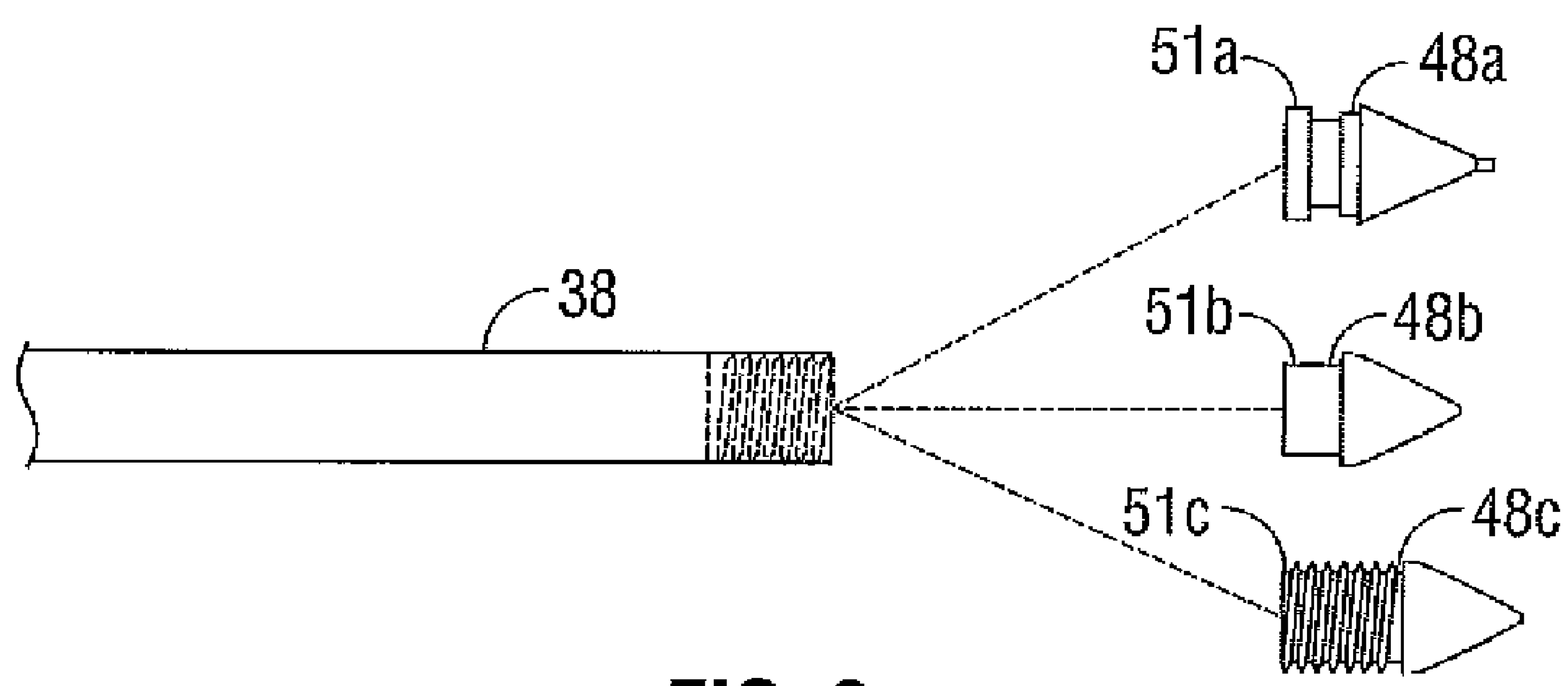


FIG. 9

# METHOD FOR CONSTRUCTING A DIPOLE ANTENNA

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a divisional of U.S. patent application Ser. No. 12/556,238, filed Sep. 9, 2009, now U.S. Pat. No. 8,069,533, issued on Dec. 6, 2011 and entitled "Method for Constructing a Dipole Antenna," the contents of which are hereby incorporated by reference herein in their entirety.

## BACKGROUND

1. Technical Field

The present disclosure relates generally to microwave applicators used in tissue ablation procedures. More particularly, the present disclosure is directed to a microwave applicator having either a liquid or solid loaded tip dipole antenna.

2. Background of Related Art

Treatment of certain diseases requires destruction of malignant tissue growths (e.g., tumors). It is known that tumor cells denature at elevated temperatures that are slightly lower than temperatures injurious to surrounding healthy cells. Therefore, known treatment methods, such as hyperthermia therapy, heat tumor cells to temperatures above 41° C., while maintaining adjacent healthy cells at lower temperatures to avoid irreversible cell damage. Such methods involve applying electromagnetic radiation to heat tissue and include ablation and coagulation of tissue. In particular, microwave energy is used to coagulate and/or ablate tissue to denature or kill the cancerous cells.

Microwave energy is applied via microwave ablation antennas that penetrate tissue to reach tumors. There are several types of microwave antennas, such as monopole and dipole. In monopole and dipole antennas, microwave energy radiates perpendicularly from the axis of the conductor. A monopole antenna includes a single, elongated microwave conductor. Dipole antennas may have a coaxial construction including an inner conductor and an outer conductor separated by a dielectric portion. More specifically, dipole microwave antennas may have a long, thin inner conductor that extends along a longitudinal axis of the antenna and is surrounded by an outer conductor. In certain variations, a portion or portions of the outer conductor may be selectively removed to provide for more effective outward radiation of energy. This type of microwave antenna construction is typically referred to as a "leaky waveguide" or "leaky coaxial" antenna.

Conventional microwave antennas typically has a long, thin inner conductor which extends along the axis of the probe and is surrounded by a dielectric material and is further surrounded by an outer conductor around the dielectric material such that the outer conductor also extends along the axis of the probe. In another variation of the probe which provides for effective outward radiation of energy or heating, a portion or portions of the outer conductor can be selectively removed. This type of construction is typically referred to as a "leaky waveguide" or "leaky coaxial" antenna. Another variation on the microwave probe involves having the tip formed in a uniform spiral pattern, such as a helix, to provide the necessary configuration for effective radiation. This variation can be used to direct energy in a particular direction, e.g., perpendicular to the axis, in a forward direction (i.e., towards the distal end of the antenna), or a combination thereof.

Invasive procedures and devices have been developed in which a microwave antenna probe may be either inserted directly into a point of treatment via a normal body orifice or percutaneously inserted. Such invasive procedures and devices potentially provide better temperature control of the tissue being treated. Because of the small difference between the temperature required for denaturing malignant cells and the temperature injurious to healthy cells, a known heating pattern and predictable temperature control is important so that heating is confined to the tissue to be treated. For instance, hyperthermia treatment at the threshold temperature of about 41.5° C. generally has little effect on most malignant growths of cells. However, at slightly elevated temperatures above the approximate range of 43° C. to 45° C., thermal damage to most types of normal cells is routinely observed; accordingly, great care must be taken not to exceed these temperatures in healthy tissue.

However, many types of malignancies are difficult to reach and treat using non-invasive techniques or by using invasive antenna probes designed to be inserted into a normal body orifice, i.e., a body opening which is easily accessible. These types of conventional probes may be more flexible and may also avoid the need to separately sterilize the probe; however, they are structurally weak and typically require the use of an introducer or catheter to gain access to within the body. Further, the manufacturing techniques for the conventional probe tend to be cumbersome, time consuming, and prohibitively expensive. Moreover, the addition of introducers and catheters necessarily increase the diameter of the incision or access opening into the body thereby making the use of such probes more invasive and further increasing the probability of any complications that may arise.

## SUMMARY

A method of fabricating a microwave antenna assembly, which is structurally robust enough for unaided direct insertion into tissue is described herein. The microwave antenna assembly is generally comprised of a radiating portion which may be connected to a feedline (or shaft) which in turn may be connected by a cable to a power generating source such as a generator. The microwave assembly may be a monopole microwave antenna assembly but is preferably a dipole assembly. The distal portion of the radiating portion preferably has a tapered end which terminates at a tip to allow for the direct insertion into tissue with minimal resistance. The proximal portion is located proximally of the distal portion.

The adequate rigidity necessary for unaided direct insertion of the antenna assembly into tissue, e.g., percutaneously, preferably comes in part by a variety of different methods. A method of fabricating an antenna includes providing a proximal portion having an inner conductor and an outer conductor, the inner conductor extending at least partially therein. The method further includes providing a distal portion disposed distally of the proximal portion, with the inner conductor extending at least partially therein. A high strength polyimide material may be injected from an inflow slot to an outflow slot of the distal portion such that the polyimide material is disposed in-between the inner conductor and a ceramic layer. The polyimide material bonds the distal portion and the ceramic layer to the proximal portion while providing mechanical strength to the distal portion.

To further aid in strengthening the antenna assemblies the inner conductor may be affixed within the distal radiating portion in a variety of ways, for instance, welding, brazing, soldering, or through the use of adhesives. Forcing the inner conductor into a tensile condition helps to force the outer diameter of the antenna into a compressive state. This bi-directional stress state in turn aids in rigidizing the antenna assembly.

To enable a compressive state to exist near the outer diameter of the distal portion, a ceramic layer may be bonded to the polyimide material. Materials such as ceramic generally have mechanical properties where fracturing or cracking in the material is more likely to occur under tensile loading conditions. Accordingly, placing the distal portion under pre-stressed conditions, may aid in preventing mechanical failure of the distal portion if the antenna were to incur bending moments during insertion into tissue which could subject the distal portion under tensile loads. The ceramic layer and a coolant jacket also act as a dielectric buffer for aiding in keeping the efficiency of the antenna constant event though tissue is changing.

## BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspects, features, and advantages of the present disclosure will become more apparent in light of the following detailed description when taken in conjunction with the accompanying drawings in which:

FIG. **1** is a schematic diagram of a microwave ablation system according to an embodiment of the present disclosure;

FIG. **2** is an isometric view of a microwave antenna assembly according to the present disclosure;

FIG. **3** is an enlarged, cross-sectional view of a portion of the microwave antenna assembly of FIG. **2**;

FIG. **4** is an enlarged, cross-sectional view of a portion of the microwave antenna assembly of FIG. **2**;

FIG. **5** is a side view of a distal portion of a feedline of the microwave antenna assembly of FIG. **2**;

FIG. **6** is an exploded view of the microwave antenna assembly according to the present disclosure;

FIGS. **7**A-**7**C are enlarged cross-sectional views of sections A-A, B-B, and C-C of the microwave antenna assembly of FIG. **4**;

FIG. **8** is a schematic diagram of a mold according to the present disclosure; and

FIG. **9** is a side view of another tip of the microwave assembly of FIG. **2**.

## DETAILED DESCRIPTION

Particular embodiments of the present disclosure will be described herein below with reference to the accompanying drawings. In the following description, well-known functions or constructions are not described in detail to avoid obscuring the present disclosure in unnecessary detail.

FIG. **1** shows a microwave ablation system **10** that includes a microwave antenna assembly **12** coupled to a microwave generator **14** via a flexible coaxial cable **16**. The microwave antenna assembly **12** may be a dipole antenna of 1.6 cm in length. In order to ablate small tumors, microwave antenna assembly **12** has a Short Radiating Section (SRS). The microwave antenna assembly **12** is capable of reducing the antenna length to one-quarter of the wavelength length required, effectively using half the length of the half wave length dipole antenna. The generator **14** is configured to provide microwave energy at an operational frequency from about 500 MHz to about 5000 MHz.

Antenna assembly **12** is generally comprised of radiating portion **18**, which may be connected by feedline **20** (or shaft) to the cable **16**. More specifically, the antenna assembly **12** is coupled to the cable **16** through a connection hub **22**. The connection hub **22** also includes an outlet fluid port **30** and an inlet fluid port **32** defined therein that are in fluid communication with a coolant jacket **38** and flow channel **13** (see FIG. **4**). The coolant jacket **38** encloses a proximal portion **42** and the feedline **20** allowing coolant fluid from the ports **30** and **32** to be supplied and circulated around a portion of the antenna assembly **12**. The ports **30** and **32** also include inner lumens defined therein (not shown) that are in fluid communication with the flow channel **13**. The ports **30** and **32** are coupled to a supply pump **34** that is, in turn, coupled to a supply tank **36**. The supply tank **36** stores the coolant fluid and maintains the fluid at a predetermined temperature. In one embodiment, the supply tank **36** may include a coolant unit which cools the returning liquid from the antenna assembly **12**. In another embodiment, the coolant fluid may be a gas and/or a mixture of fluid and gas.

Assembly **12** also includes a tip **48** having a tapered end **24** that terminates, in one embodiment, at a pointed end **26** to allow for insertion into tissue with minimal resistance at a distal end of the radiating portion **18**. In those cases where the radiating portion **18** is inserted into a pre-existing opening, tip **48** may be rounded or flat.

FIG. **2** illustrates the radiating portion **18** of the antenna assembly **12** having an unbalanced dipole antenna **40**. The dipole antenna **40** includes a proximal portion **42** and a distal portion **44** interconnected by an injection molded seal **46**. The distal portion **44** and the proximal portion **42** are of different, unequal lengths so that the dipole antenna **40** is unbalanced. In one embodiment, the distal portion **44** may be longer than the proximal portion **42**. In one embodiment, in which the feedline **20** is formed from a coaxial cable, the outer conductor **56** and the inner insulator **52** may be sliced off to reveal the inner conductor **50**, as shown in FIG. **5**.

The dipole antenna **40** is coupled to the feedline **20** that electrically connects antenna assembly **12** to the generator **14** (FIG. **1**). The assembly **12** includes a coolant jacket **38** coupled to a fluid seal **8** (see FIG. **4**), which in turn is coupled to an injection molded seal **46**. The coolant jacket **38** may be formed from a medical grade metal. The injection molded seal **46** may be made of a high strength polyimide resin. The polyimide resin may be VESPEL® sold by DuPont of Wilmington, Del.

In one embodiment, the injection molded seal **46** is fabricated by injecting a polyimide material into an inflow slot **9**A to an outflow slot **9**B of the distal portion **44**. As shown in FIG. **3**, the injection molded seal **46** is disposed in-between a distal radiating section **44** and the ceramic layer **2**. The ceramic layer may be made of alumina ceramic. The injection molded seal **46** bonds the distal portion **44** and the ceramic layer **2** to the proximal portion **42** while providing mechanical strength to the distal portion **44**. As shown in FIGS. **3**-**4**, the feedline **20** includes an inner conductor **50** (e.g., wire) surrounded by an inner insulator **52**, which is then surrounded by an outer conductor **56** (e.g., cylindrical conducting sheath). The inner and outer conductors **50**, **56** may be constructed of copper, gold, stainless steel or other conductive metals with similar conductivity values. The metals may be plated with other materials, e.g., other conductive materials, to improve their properties, e.g., to improve conductivity or decrease energy loss, etc. In one embodiment, the inner insulator layer **52** is formed from a fluoropolymer, such as tetrafluorethylene, perfluorpropylene, and the like, and has a thickness of about 0.011-0.013 inches.

In one embodiment, the feedline **20** may be formed from a coaxial semi-rigid or flexible cable having a wire with a 0.047" outer diameter rated for 50 Ohms. The inner insulator **52** may have a dielectric constant from about 1 to 10.

Overlaying the outer conductor **56** is a flow channel **13** that cools the majority of the proximal portion **42**. The flow channel **13** is in fluid communication with fluid ports **30**, **32**. A polyimide inflow sleeve **15** is disposed in the flow channel **13** to create an inflow channel **17***a* and an outflow channel **17***b* for the coolant. The abundance of cooling fluid from the concentric in-flow design of the polyimide inflow sleeve **15** in the flow channel **13** acts as a lossy material to absorb the microwave energy as well as to cool the feedline **20** for percutaneous use.

In another embodiment, the fluid seal **8** may also be formed from solid wire machined component or a cylindrical conductor filled with solder. The fluid seal **8** is thereafter coupled to the outer conductor **56** (joint E), as shown in FIGS. **3-4**. This may be accomplished by soldering the fluid seal **8** to the outer conductor **56**, such as by melting the solder of the fluid seal **8** and inserting the outer conductor **56** therein.

The distal portion **44** includes a conductive member **45** that may be formed from any type of conductive material, such as metals (e.g., copper, stainless steel, tin, and various alloys thereof). The distal portion **44** may have a solid structure and may be formed from solid wire (e.g., 10 AWG). In another embodiment, the distal portion **44** may be formed from a hollow sleeve of an outer conductor of coaxial cable or another cylindrical conductor. The cylindrical conductor may then be filled with solder to convert the cylinder into a solid shaft. More specifically, the solder may be heated to a temperature sufficient to liquefy the solder within the cylindrical conductor (e.g., 500° F.), thereby creating a solid shaft.

As shown in FIGS. **2** and **3**, the distal portion **44** is coupled to the tip **48**, which may be formed from a variety of heat-resistant materials suitable for penetrating tissue, such as metals (e.g., stainless steel) and various thermoplastic materials, such as poletherimide, polyimide thermoplastic resins, an example of which is Ultem® sold by General Electric Co. of Fairfield, Conn. The tip **48** may be machined from various stock rods to obtain a desired shape. The tip **48** may be attached to the distal portion **44** using various adhesives, such as epoxy seal. If the tip **48** is metal, the tip **48** may be soldered to the distal portion **44** or may be machined as one continuous component.

FIG. **6** is an exploded view of the microwave antenna assembly **12**. The microwave antenna assembly **12** includes a proximal portion **42** and a distal portion **44**. The proximal portion **42** may include an inner conductor **50**, an inner insulator layer **52**, and an outer conductor **56**. The proximal portion **42** may also include a flow channel **13** defined therein (not shown) that includes an inflow channel **17***a* and an outflow channel **17***b* that are separated by a polyimide inflow tube **15**. The polyimide inflow tube **15** (not shown) may be inserted into a pocket of a fluid seal **8** to cool the proximal portion **42**. The distal portion **44** includes an inner conductor **50**, a distal radiating section **51**, an injection molded seal **46**, and a ceramic layer **2**.

FIGS. **7A-7C** are enlarged cross-sectional views of sections A-A, B-B, and C-C of the microwave antenna assembly of FIG. **4**. FIG. **7A** illustrates a cross section at section A-A. Section A-A illustrates from the inside towards the outer surface, an inner conductor **50**, insulator **52**, outer conductor **56**, flow channel **13** (specifically inflow channel **17***a*), polyimide inflow tube **15**, flow channel **13** (specifically outflow channel **17***b*), and coolant jacket **38**.

FIG. **7B** illustrates a cross section at section B-B. Section B-B illustrates from the inside towards the outer surface, an inner conductor **50**, insulator **52**, outer conductor **56**, flow channel **13** (specifically inflow channel **17***a*), polyimide inflow tube **15**, flow channel **13** (specifically outflow channel **17***b*), fluid seal **8**, and coolant jacket **38**. FIG. **7C** illustrates a cross section taken at section C-C of the distal portion. Section C-C illustrates from the inside towards the outer surface, an inner conductor **50**, insulator **52**, an injection molded seal **46**, and a ceramic layer **2**.

Referring back to FIGS. **2-4**, the microwave antenna assembly **12** may be manufactured in various steps. A coaxial cable that includes the inner conductor **50**, insulator layer **52**, and outer conductor **56** may be manufactured and assembled as one component. The outer conductor **56** may be soldered to the fluid seal **8**, for example at joint E, to provide the electrical joint, if needed. The coolant jacket **38** may be bonded, threaded, laser welded, soldered or crimped to the fluid seal **8** at joint D. The coolant jacket **38** and the fluid seal **8** may be assembled as one component. The polyimide inflow tube **15** may be configurable to slide into a pocket of the fluid seal **8**.

The inner conductor **50** is configured to slide inside a hole of the distal portion **44**. The distal portion **44** is affixed to a distal end of the inner conductor **50** by laser welding, soldering or crimping at joint F. The coaxial cable, coolant jacket **38**, proximal portion **42**, ceramic layer **2**, and distal portion **44** are placed into an injection mold cavity.

FIG. **8** is a schematic diagram of a mold according to the present disclosure. The mold **53** is used to inject a high strength polyimide material in-between the inner conductor **50** and the ceramic layer **2**. The mold **53** includes mold halves **111***a* and **111***b*. Mold halves **111***a* and **111***b* include portions/cavities to receive coaxial cable, coolant jacket **38**, fluid seal **8**, ceramic layer **2**, and trocar tip **48**. Mold halves **111***a* and **111***b* also include an inflow slot **9**A and an outflow slot **9**B. The mold halves **111***a* and **111***b* are clamped tightly together and heated polyimide is injected into the inflow slot **9**A until the heated polyimide fills into outflow slot **9**B defined therein. The polyimide flows into a cavity to form a uniform layer of polyimide layer along the distal portion **44**. The polyimide material bonds the distal portion **44** and the ceramic layer to the proximal portion while providing mechanical strength to the distal portion.

In another embodiment, the mold **53** does not include a cavity for the trocar tip **48**. In such an embodiment, when the injection molding process is complete, the antenna assembly **12** is finished by installing the trocar tip **48**. FIG. **9** illustrates various shapes and forms of a trocar tip **48** installed onto a sheath **38**, namely a stainless steel tip **48***a* and a dielectric tip **48***b*. Both tips **48***a* and **48***b* include insertion bases **51***a* and **51***b* having an external diameter that is smaller than diameter of the tips **48***a* and **49** allowing for easier insertion into a sheath **38**. The configuration also provides for a better seal between the tip **48** and the sheath **38**. In another embodiment, the sheath **38** and tip **48***c* maybe threaded so as to attach to each other. Therefore, the tip **48***c* may be tightly screwed into the sheath **38**.

The described embodiments of the present disclosure are intended to be illustrative rather than restrictive, and are not intended to represent every embodiment of the present disclosure. Various modifications and variations can be made without departing from the spirit or scope of the disclosure as set forth in the following claims both literally and in equivalents recognized in law.

What is claimed is:

**1**. A method of constructing a dipole antenna, comprising the steps of:

providing an upper mold half and a lower mold half having mating surfaces that mate together to form cavities to receive a feedline, radiating portion, and ceramic portions therein, each of the upper and lower mold halves includes first and second slots, respectively, to receive a polyimide material;

placing the feedline into the respective cavity, the feedline including an inner conductor, an outer conductor and an inner insulator disposed therebetween;

placing the radiating portion into the respective cavity, the radiating portion including an unbalanced dipole antenna having a proximal portion and a distal portion of different lengths, wherein the proximal portion includes at least a portion of the inner conductor and the inner insulator and the distal portion includes a conductive member;

placing the ceramic portions into the respective cavity;

mating the upper mold half and the lower mold half together; and

depositing the polyimide material into each of the first slots through the second slots and upon cooling, the polyimide material adheres to the distal and ceramic portions to the proximal portion.

**2**. The method of constructing the dipole antenna in accordance with claim **1**, wherein the distal portion is affixed to a distal end of the inner conductor by at least one of laser welding, soldering, and crimping.

**3**. The method of constructing the dipole antenna in accordance with claim **1**, further comprising the step of joining a trocar adapted to receive a distal end of the inner conductor.

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